Studies on the diversity of soil animals in Taishan Mountain

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Abstract: Taishan Mountain has diverse habitats and abundant groups of soil animals. Five habitats, *Platycladus orientalis* forest, *Pinus densiflora* forest, *Robinia pseudoacacia* forest, *Pinus tablaeormis* forest and Grassland, were selected and the diversity of soil animals in different habitats in Mt. Taishan were investigated and studied in 1997-1999. Totally 52 groups of soil animals were found, belonging separately to 7 Phyla, 11 Classes, 25 Orders and 28 suborders or families. There exists remarkable difference in groups, quantity and diversity of soil animals among the five habitats. Grassland habitat was the highest and *Pinus densiflora* forest was the lowest in groups, quantities, Density-group index (*DG*) and Diversity index of comparing many communities (*DIC*) of soil animals. Shannon-Wiener's diversity index (*H'*) for soil animals of different habitats was in order of *Platycladus orientalis* forest>*Pinus densiflora* forest>*Pinus tablaeormis* forest>Grassland>*Robinia pseudoacacia* forest, Pielou's equality index (*J'*) was *Platycladus orientalis* forest>Pinus densiflora forest>Grassland>*Pinus tablaeormis* forest>*Robinia pseudoacacia* forest, and Simposn's dominant index (*C*) was Grassland>*Robinia pseudoacacia* forest>*Pinus tablaeormis* forest>*Pinus densiflora* forest>*Platycladus orientalis* forest. The H index and J index of macro-soil animal all were larger than that of mid-small soil animal. Clustering analysis for five soil animal communities and ordination analysis for community structure by multidimensional scaling (MDS) were made and completely identical results were obtained. Soil animal communities of five habitats were divided into 3 groups.

Keywords: Diversity; Soil animals; Habitat; Taishan Mountain

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Introduction

Mountainous region has higher biodiversity because of its diverse habitats, comparing to plain area. Today, populations of the world have been quickly increasing and environment has been destroyed greatly, so that protecting biodiversity of mountainous region has become an important research task of hill ecology. Diversity of soil animal is an important part of biodiversity in mountainous region and plays an important role in maintaining stabilization of ecosystem of mountain region and accelerating material circulation and energy flow in ecosystem (Watanabe *et al.* 1977; Kevan 1955). Up to date, reports on diversity of soil animal in Taishan Mountain haven't been found. The authors from 1997 to 1999 firstly carried out an investigation on diversity of soil animal in Taishan Mountain. The purpose of this study is to provide basic data for protecting ecological environment and diversity of soil animal in Taishan Mountain.

Study area and methods

The study work was carried out in Taishan Mountain (36°5'~36°15' N latitude and 117°5'~117°24' E longitude) located in Shandong Province. Geology of Taishan Mountain is very old. Eroded by wind and scoured by water for long time, great deal high apices and clough have been formed. The highest peak, called Yuhuang Ding, is an altitude of 1 545 mm above sea level. Local climate belong to warm temperate zone monsoon climate. It gets much rain in summer and cold and dry in winter, with an annual average rainfall of 750 mm, an annual average temperature of 12.9℃ and a frost-free period of 186-196 d. Soil and vegetation types are multiple and their vertical distribution is evident along elevation gradient.

According to vertical variation of vegetation and soil and as well as human activity influence, Five habitats have been selected as study sites: *Platycladus' orientalis* forest, *Pinus densiflora* forest,

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Robinia pseudoacacia forest, *Pinus tablaerormis* forest, Grassland. Sampling size is 50 cm×50 cm×15 cm for large-sized soil animal and 5 cm×5 cm×4 cm for middle-small-sized soil animals (1/4 soil quantity was taken for Feuchtluftiere). Depth sampling was made at 0~5-cm, 5~10-cm, 10-15~cm soil layer. Soil animal specimens were separated and extracted from the samples by hand-picking method (for large-sized soil animal), Tullgren method (for middle-small-sized soil animal) and Baermann method (for Feuchtluftiere) in the laboratory. At last, the specimens were identified according to J. AOKI and parts of entomological classification handbook (AOKI 1973; Yin *et al.* 1992; Zhong 1985; Jin 1985).

Results and analysis

Habitat is a most suitable environment on which survival of organisms depends. In mountainous region, the habitat types become diverse with altitude rising, which makes the mountainous region rich in biodiversity. 52 groups (4 330 individuals) of soil animals were collected (not including protozoa) during the investigation, belonging to 7 Phyla, 11 Classes and 25 Orders and 28 suborders or families. The Dominant groups are Nematoda and Formicidae and common groups are Acarina, Enchytraeidae, Coleopterd, Collembola, Diptera, Chilopoda, Gastopoda, Homoptera, which account for 94.27% of the total numbers of soil animals acquired. Comparing to the dominant and common groups, the rare animals are rich in groups though their individual numbers are less, accounting for 64% of the total groups (base on 28 suborders), and they make foundational contribution to biodiversity in Taishan Mountain. The conditions of five habitats in Taishan Mountain are different from each other, so group and quantities of soil animals are also different (Fig.1). Two dominant groups have wide distributions in Taishan Mountain and could be found in all habitats. Distributions of the common groups and rare animals varied with environment changes. Some rare animals could only be met in one forest habitat, for instance, Blattariae lives in *Platycladus orientalis* forest, Pseudoscorpio-nida lives in *Robinia pseudoacacia* forest, Turbellaria lives in *Pinus tablaerormis* forest, Protura lives in Grassland. They have function of indicating their habitats. Since *Platycladus orientalis* forest and *Pinus densiflora* forest distributed at lower altitudes have rough soil quality and less organic matter, contain less water in soil, and appearance of vegetation is sparseness and out of order, with scarce undergrowth, the groups, individual numbers and density of soil animals were lower in these habitats. In *Robinia pseudoacacia* forest, plants are all defoliate plant and soil organic matter is more richness, but owing to that it is located near Zhongtianmen in Taishan Mountain, where was trampled by tourists and soil surface becomes harden gradually, the quantity of soil animals got less. *Pinus tablaerormis* forest distribute at northern slope of Taishan Mountain with high altitude and rich precipitation, where the vegetation grow luxuriantly, the species of shrubs and grasses are abundant, and organic matter and litter in soil are richness, so the group number of soil animals in this habitat was as many as that in *Robinia pseudoacacia* forest, but the quantity of soil animals in the former was much more than that in the latter. Grassland is located at top of Taishan Mountain, where is humid and foggy, the coverage of vegetation is 100% and soil organic matter is rich, so that groups and quantity of soil animals in grassland habitat were most high in five habitats.

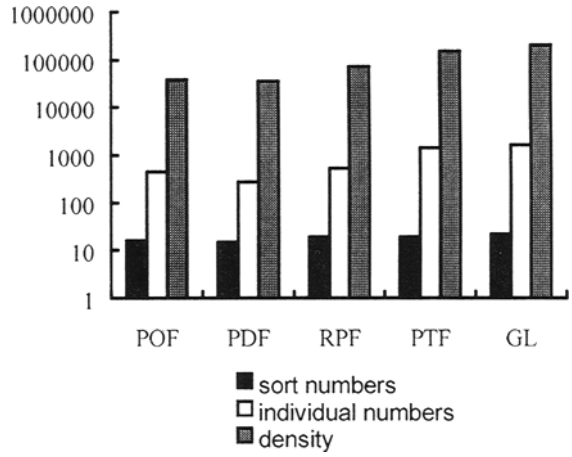

Fig 1. Quantity index of soil animal community in five types of habitat in Taishan Mountain

POF—*Platyclandus orientalis* forest; PDF—*Pinus densiflora* forest; RPF—*Robinia pseudoacacia* forest; PTF—*Pinus tablaeromis* forest; GL--Grassland

Note: data in Graph were obtained by logarithmic transforming

Based on study of group and quantity of soil animal, according to major taxon (not including protozoa), diversity indices were calculated by following equations (Pielou 1975; Clarke 1993; Magurran 1988; Ma 1994):

Shannon-Wiener's diversity index:

$$H' = -\sum_{i=1}^{s} P_i \ln P_i \quad (1)$$

Pielou's equality index:

$$J' = H' / \ln S \quad (2)$$

Simpson's dominant index:

$$C = \sum (n_i / N)^2 \quad (3)$$

In equation (1), (2), (3): $P_i = n_i / N$; n_i is individual numbers of each group; N is individual numbers of all groups; S is number of group.

Density-group index (DG):

$$DG=(g/G)\sum_{i=1}^{g}(\frac{D_i C_i}{D_{i\max} C}) \quad (4)$$

Diversity index of comparing many communities (DIC):

$$DIC=\frac{g}{G}\sum_{i=1}^{g}[1-(\frac{|X_{i\max}-X_i|}{X_{i\max}+X_i})]\frac{C_i}{C} \quad (5)$$

In formulas (4), (5): D_i is individual number (or biomass) of group I, D_{imax} is biggest individual number of group I in all communities, g is number of group in a community, G is total number of groups in all communities, C is number of community, C_i is appeared times of group I in C communities, X_{imax} is biggest ones of individual numbers of group I in many communities, X_i is individual numbers of group I in measured community.

Jaccard's resemblance index:

$$q = c/a+b+c \quad (6)$$

Where: a is number of group in one community, b is number of group in another community, c is number of same group in a and b communities.

According to above equations, diversity indices of soil animals in every habitat in Taishan Mountain have been calculated (Table.1). H' index depend on group number and even distribution of individual number of every group in each community. In the five habitats, grassland had the highest group number of soil animals, followed by *Pinus tablaerormis* forest, *Robinia pseudoacacia* forest. In terms of group, grassland habitat should have the highest H' index, but because the individual numbers of soil animal in grassland habitat mostly focused on Nematoda, Acarina, Hymenoptera, which accounted for 81.62% of the total numbers in this community, and had an uneven distribution for individual numbers of each group in this community, so its H' index was lower. Similarly, *Pinus tabulaeformis* forest Robinia pseudoacacia forest also had lower H' indices. That is because the individual numbers of soil animals in *Pinus tabulaeformis* forest are dominated by Nematoda, Hymenoptera, Aearina, which account for 82.8% of total number of individuals of soil animals in this community, and Nematoda, Aearina, Coleoptera in *Robinia pseudoacacia* forest also dominant taxon, accounting for 85.96%. Though the number of group was lower in *Platycladus orientalis* and *Pinus densiflora* forest, the distribution of individual numbers of every group was more even, so their H' indices was higher.

Table 1. Diversity index of soil animal community in Taishan Mountain

Habitat type	H'	J'	C	DG	DIC
Platycladus orientalis forest	2.91	1.05	0.18	4.22	4.55
Pinus densiflora forest	2.47	0.87	0.27	2.13	2.77
Robinia pseudoacacia for est.	2.07	0.80	0.41	4.24	5.43
Pinus tablaerormis forest	2.21	0.84	0.37	6.05	6.71
Grassland	2.10	0.86	0.42	7.90	8.97

From Table 1, H' index was in order of *Platycladus orientalis* forest>*Pinus densiflora* forest>*Pinus tablaerormis* forest>Grassland> *Robinia pseudoacacia* forest, J' index was *Platycladus orientalis* forest>*Pinus densiflora* forest>Grassland>*Pinus tablaerormis* forest>*Robinia pseudoacacia* forest, C index was Grassland>*Robinia pseudoacacia* forest>*Pinus tablaerormis* forest> *Pinus densiflora* forest> *Platycladus orientalis* forest.

DG and *DIC* index was used for comparing their diversities among many communities, and they were not affected by individual numbers of every group in a community. The way to compare one group in a community with same group in another community is suitable for comparison between communities of soil animals. With analyzing Table 1, it is learnt that soil conditions of *Pinus densiflora* forest was the worst and extremely unfavorable to existence of soil animals, so that its *DG* index and *DIC* index were the lowest in the five habitats. Since *Platycladus orientalis* forest and *Robinia pseudoacacia* forest are frequently disturbed by human being and their soil conditions are moderate, lying between *Pinus densiflora* forest and Grassland, so *DG* index and *DIC* index were moderate. As for water condition of soil and plant environment, *Robinia pseudoacacia* forest was better than *Platycladus orientalis* forest, therefore *DG* and *DIC* index of soil animal in *Robinia pseudoacacia* forest was higher than those in *Platy-cladus orientalis* forest. The environmental condition of Grassland was the best in five habitats, so *DG* index and *DIG* index of soil animals were the highest.

Comparing to mid-small animal, the soil macro-animal has larger moving range, higher group

number and even distribution in individual number of every group. Nematoda and Aearina were dominating over in individual number of soil mid-small animal, accounting for 69.77% of total numbers of soil mid-small animal. In Taishan Mountain, H' and J' indices of soil macro-animal were higher than those of soil mid-small animals (Fig 2).

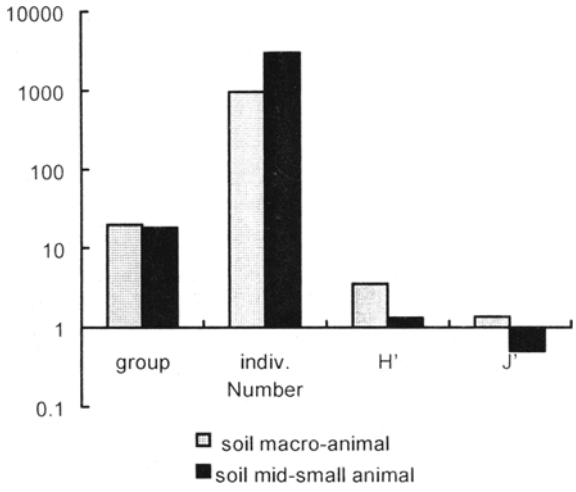

Fig 2. Diversity index of soil macro-animal and mid-small animal community in Taishan mountain

Note: data in Graph were obtained by logarithmic transforming

Using Jaccard's index of similarity and the unweighted arithmetic average sorting strategy, cluster analysis was applied to samples groups (Fig.3). Fig.3 shows that soil animals of five habitats were grouped into 3 main clusters: *Robinia pseudoacacia* forest, Grassland and *Pinus tablaerormis* forest for one cluster, *Pinus densiflora* forest for one cluster, and *Platycladus orientalis* forest is the other cluster. The composition of soil animal in *Robinia pseudoacacia* forest and that in Grassland was the most similar in five habitats, The reason that bring on this result is altitude of above three habitats all are higher, conditions of water and soil are similar, and life types of plant of *Robinia pseudoacacia* forest and Grassland are more similar, and this two habitats located around important site of tourism in Taishan mountain and were disturbed strongly by human. Otherwise *Pinus tablaerormis* forest located at northern slope in Taishan Mountain and there were few tourists and less human disturbance. *Platycladus orientalis* forest located at the foot of Taishan Mountain, pollution which livelihood and production of residents around it brought about impacted extremely on community of soil animal in *Platycladus orientalis* forest, so its composition of soil animal was extremely different from those of other four habitats. Condition of soil in *Pinus densiflora* forest was the worst and its group numbers of soil animal was the lowest in five habitats, *Pinus densiflora* forest also differed evidently from other habitats in composition of soil animal.

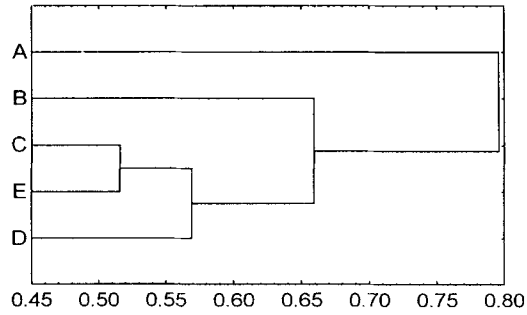

Fig 3. Clustering branches of soil animal community at different habitats in Taishan mountain

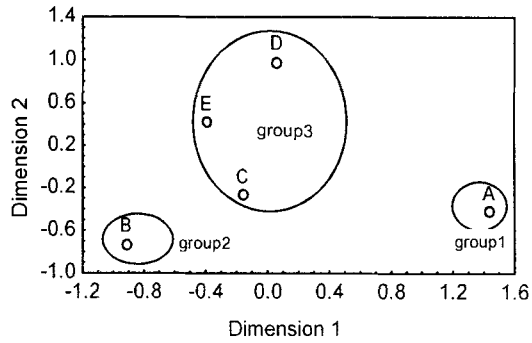

Fig 4. MDS ordination plot of samples taken from five types of habitat in Taishan mountain

A ranked triangular similarity matrix was constructed using the Jaccard similarity index. The soil animal community of five habitats was analyzed using multidimentional scaling (MDS). Subsequent ordination produced by MDS was shown in Fig.4. Compared Fig. 3 with Fig. 4, they hold perfectly identical results. The result obtained with MDS may appear more object as compared with clustering analysis, because MDS may continuously show similar relation of organism composition between sample sites, so the more similar organism composition between sample sites are, the nearer distance between their points are in MDS plot. Oppositely, the farther distance between their points are, the bigger similar are. Soil animals of five habitats were also divided into three main groups in Fig. 4, group 1 is *Platycladus orientalis* forest and its point lie the right of MDS plot, group 2 is *Pinus densiflora* forest and located left, group 3 included *Robinia pseudoacacia* forest, Grassland and *Pinus tablaerormis* forest and were located middle of plot. The distance between point of group 1 and that of group 2 was the farthest in three

groups, which shows group 1 and group 2 were the most different in composition of soil animal. But the similarity of soil animal of three habitats in group 3 were higher. Thereby the similarity of group 2 with group 3 was higher than that of group 1 with group 3.

Conclusions

The vertical changes of habitats have appeared with increasing of the altitude in Taishan Mountain, group number of soil animals was abundant, 52 groups have been obtained, they belongs to 7 Phyla, 11 Classes, 25 Orders and 28 suborders or families.

H', J', C, DG and *DIC* index of soil animal of every habitats were different from each other. In five habitats, H' index was the order of *Platycladus orientalis* forest > *Pinus densiflora* forest > *Pinus tablaerormis* forest > Grassland > *Robinia pseudoacacia* forest, J' index was *Platycladus orientalis* forest > *Pinus densiflora* forest > Grassland > *Pinus tablaerormis* forest>*Robinia pseudoacacia* forest, *C* index was Grassland>*Robinia pseudoacacia* forest>*Pinus tablaerormis* forest>*Pinus densiflora* forest>*Platycladus orientalis* forest, *DG* index and *DIC* index were consistent and they were Grass-land>*Pinus tablaerormis* forest>*Robinia pseudoacacia* forest>*Platycladus orientalis* forest>*Pinus densiflora* forest.

H' and *J'* dex and group number of soil macro-animal all were larger than those of soil mid-small animal in Taishan mountain.

Soil animals of five habitats all were divided into three main groups with clustering analysis and MDS. The similarity between *Platycladus orientalis* forest and *Pinus densiflora* forest was the lowest, but the ones of *Robinia pseudoacacia* forest and *Pinus tablaerormis* forest and grassland was higher, and the ones between *Robinia pseudoacacia* forest and *Pinus tablaerormis* forest was the highest among three habitats.

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